



The Most Common Questions and Answers about Cloud Seeding

Cloud seeding, often called weather modification, is not something most of us learned any details about in school. If we graduated more than five or ten years ago, much of what might have been said would not apply today. Consequently, there are many questions about the technology. This brochure addresses the most common ones, and provides the interested reader with some ideas where more information can be found. If you would like to learn more about cloud seeding in North Dakota, check out the Atmospheric Resource Board's web site at www.swc.state.nd.us/arb/.

Cloud Processes and Seeding Methods

1. What does cloud seeding do to a cloud?

Cloud seeding improves a cloud's ability to produce precipitation by adding to a cloud tiny particles called ice nuclei (which water needs to freeze). These nuclei help the cloud produce precipitation by freezing **supercooled liquid water (SLW)**, which is liquid cloud droplets cooled to temperatures below freezing. This increases the precipitation efficiency of the seeded cloud.

2. Are all clouds potentially good candidates for seeding?

No. For summertime cloud seeding, only clouds that possess a sustained updraft of moist air, a lack of natural ice, and grow to heights cold enough to contain supercooled liquid water are suitable for cloud seeding.

3. What are clouds seeded with?

North Dakota clouds are seeded with two different types of agents: silver iodide complexes, artificial ice nuclei, which provide a crystalline structure on which supercooled liquid water (SLW) droplets can freeze; and dry ice (frozen carbon dioxide), which at -104°F, is so cold that it freezes SLW droplets by thermal shock.

4. How long after seeding before a treated cloud starts to change?

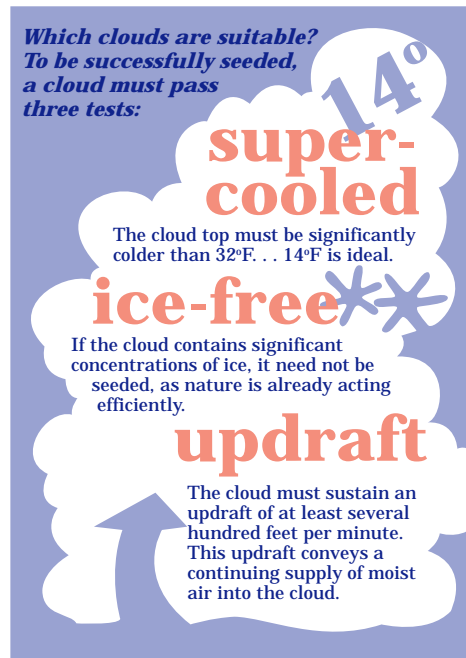
Seeding effect can range from almost immediate to up to 30 minutes depending on the seeding delivery method (**direct injection** at cloud top, or **base seeding**, releasing seeding agent in the updraft at the cloud base). Direct injection is more immediate, but involves flying in-cloud and working within project safety requirements and FAA regulations. Updraft treatment at the cloud base is easier to accomplish, but requires the seeding agent to be transported by the cloud's updraft to where it can become effective, and thus takes a little longer.

5. How long after seeding ends before a treated cloud reverts back to normal?

A range of time is also required before a seeded cloud fully reverts to its natural characteristics. Factors include the amount of agent introduced into the cloud, the size and vigor of the cloud, and its ability to process the additional ice nuclei. Between 15 and 30 minutes would be average.

6. Who decides when clouds are seeded?

The radar meteorologist is the director of operations for cloud seeding



missions. A number of factors play a part in the decision-making process, including safety criteria, radar information, pilot observations, and aircraft instrument data.

7. If a cloud is seeded, does it rain somewhere other than where it would have?

Seeded storms often rain over larger areas than unseeded storms. This means that some areas that would not have received rain often do as a result of seeding. By seeding developing clouds before they start to produce precipitation, the precipitation process is accelerated and rain falls sooner, and from smaller clouds than it would naturally. Some redistribution of rainfall can occur within the scope of the storm itself, with computer models suggesting that regions of very intense precipitation may be slightly reduced while the total storm rain volume is increased.

8. How are seeding chemicals delivered to suitable clouds?

In North Dakota, all seeding is done by aircraft. Base seeding aircraft release seeding agent into updrafts from below the developing storm using a combination of wing-tip generators and burn-in-place flares. Cloud top seeding aircraft use ejectable flares and dry ice, which are released directly into the supercooled cloud top.

9. Isn't flying aircraft around thunderstorms dangerous?

It can be if pilots are not properly trained. However, all the pilots that fly seeding aircraft on the North Dakota project are trained for this activity through either classroom and intern experience, field experience with a qualified weather modification pilot instructor, or both.

Climate and Environment

10. What effects do cloud seeding chemicals have on the environment?

There is no evidence of seeding chemicals having a negative effect on the environment or on humans. The silver concentration in rainwater from a seeded storm is well below the acceptable environmental concentration of 50 micrograms per liter as set by the U.S. Public Health Service. Also, the concentration of iodine in iodized salt used for human consumption is far above the concentration found in rainwater from seeded clouds. At the rate that silver iodide was distributed in North Dakota target counties in 1998, a busier than average year, it would take about 75 years for one gram of silver iodide (1/28th of an ounce) to be evenly spread out over an area equal to a full-sized basketball court!

11. Does rain water from a seeded cloud taste or smell different than natural rain?

No. There is no discernible difference between rainwater from a seeded cloud and rainwater from a non-seeded cloud.

12. Can cloud seeding change weather patterns?

No. Cloud seeding changes individual clouds or groups of clouds, but movement is largely determined by atmospheric winds which cloud seeding cannot affect.

13. Can cloud seeding end droughts?

Though drought is sometimes the impetus for implementing a cloud seeding program, it is not generally advocated for such purposes. The reason for this is that droughts are caused by prolonged periods that do not produce clouds conducive to precipitation production. Therefore, cloud seeding opportunities during these periods would be very limited and results would be marginal (see question #2). A long-term and well designed cloud seeding program can potentially soften the impact of drought, however, since increased precipitation production before and after drought would temper the reduction of rainfall during the drought period.

Atmospheric Research and Program Evaluation

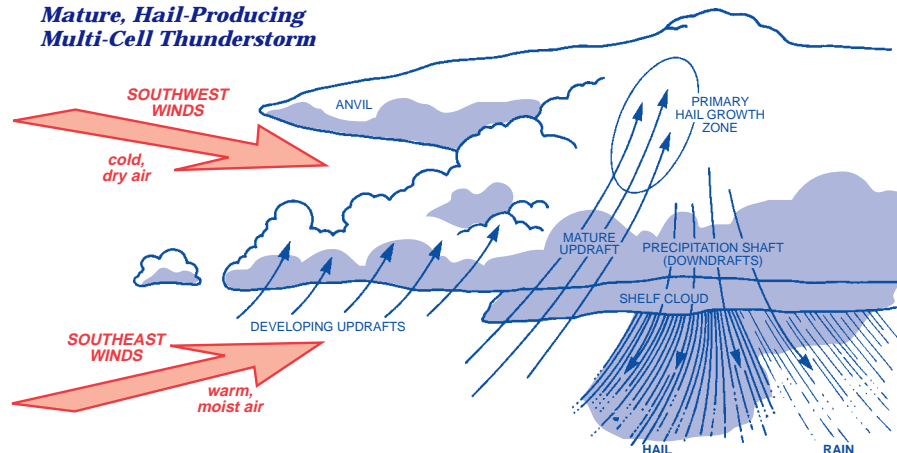
14. How do we know what goes on inside clouds?

A number of scientific research experiments have been conducted, many in North Dakota, from which we have learned much about the basic processes of cloud initiation, development and decay. Much of what has been learned has been applied to cloud seeding technology, thereby making cloud seeding more effective now than ever before. However, further research still needs to be done to answer remaining questions and further improve cloud seeding practices.

15. How can we determine the effects of seeding?

Seeding effects and benefits can be demonstrated in a number of ways. The most direct method would be to conduct a project over several years in which half of the storms were randomly seeded and the resulting precipitation from the seeded and unseeded storms were compared. The problem with this method, though, is that project sponsors usually want all of the seedable clouds treated, not just half, to attain the maximum benefit from the program. Evaluations using crop-hail insurance data, crop yield data, or rainfall and hail data are useful if done properly. These evaluations require long term relationships to be established between seeded and unseeded areas, and a long period of operations for comparison purposes, but do not require that only half of the suitable clouds be treated.

Mature, Hail-Producing Multi-Cell Thunderstorm

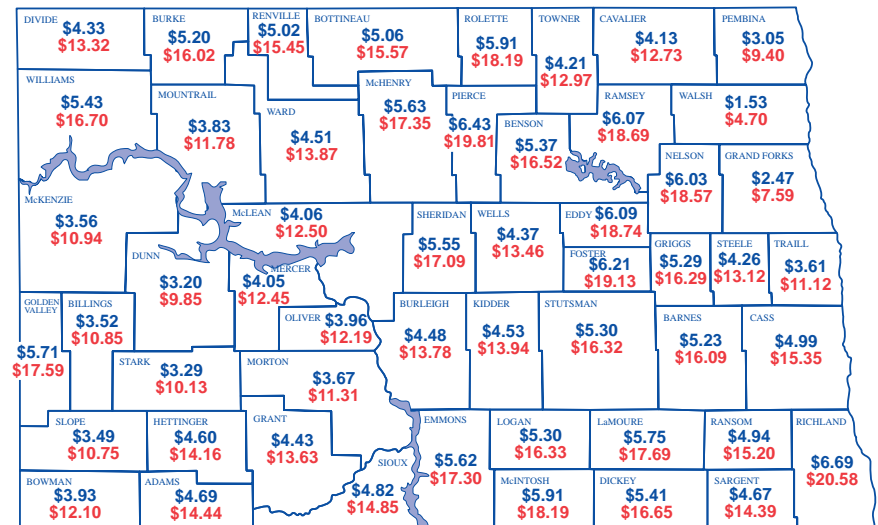


16. What is the dollar-impact of cloud seeding in North Dakota?

Sell and Leistritz (1998) studied the economic impacts of cloud seeding in North Dakota. Eight of North Dakota's most common crops, all wheat, barley, sunflowers, soybeans, dry edible beans, corn grain, oats, and flax were evaluated for impacts of a statewide cloud seeding program. Results were based on a 45 percent reduction in crop losses (Smith, et al., 1997), and a 15 percent increase in rainfall (Changnon and Huff, 1972). The annual crop production increase was \$34.4 million for hail reduction and \$52.2 million for rainfall enhancement statewide. This \$86.6 direct impact results in an increase in total business activity of \$267 million or an average of \$14.52 per planted acre. Additionally, the estimated \$3.2 million annual cost of operating a cloud seeding program statewide is more than offset by the \$5.1 million in increased tax revenues. Thus, the program more than pays for itself. Additional benefits to other crops, livestock and reduction of property damage were not included in this report, but are also thought to be substantial.

Annual Average Increased Gross Returns Due to Reduced Hail & Enhanced Rainfall

\$0.00= Increased Production per planted acre
\$0.00= Total Business Activity per planted acre



17. Why does hail sometimes fall from seeded storms?

Cloud seeding for hail suppression is just that: hail **suppression**, not hail **elimination**. The most recent study of crop-hail data suggests that the program reduces crop-hail damage by 45 percent. Hail does still occur in areas with hail suppression cloud seeding. The reasons for this are many, but they involve storm structure (seeding works better on some storm types than others), the ability to safely and effectively seed targeted storms (sometimes safety criteria preclude effective treatment of targeted storms), and working with limited resources (sometimes there are more storms occurring at one time than there are resources available to adequately seed them). Also, occasionally storms already containing hail enter the target areas. This hail will fall eventually and nothing can be done to prevent it.

18. Why do some thunderstorms produce hail, while others don't?

Hail often occurs when instability is great, and when other factors such as

strong winds aloft are also present. Thunderstorm ingredients include: atmospheric instability (warm air at the surface, and cold air aloft), abundant moisture, and a weather feature such as a cold or warm front to initiate storm development. While a small percentage of storms produce hail on the ground, a much larger percentage develop hail during their life cycle that falls and melts before it reaches the ground.

19. Does cloud seeding make it dry downwind? (Or, does cloud seeding result in excess precipitation downwind?)

There is no scientific evidence that cloud seeding in one area produces dry conditions downwind of that area. On the contrary, evidence suggests a slight increase in precipitation downwind (up to 90 miles in extreme cases) that diminishes with increasing distance from the target area (See question #5).

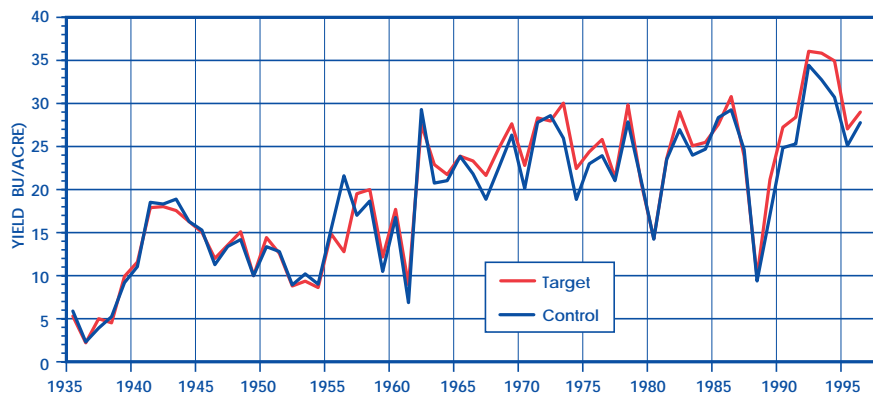
20. Do urban residents benefit from cloud seeding, or is it just for the farmers?

Although the program was started to help farmers mitigate hail damage to crops, the reduction of hail size and amount also reduces hail damage to homes, vehicles, and other property in the target counties. In fact, reduction of property damages has provided the impetus for an insurance industry-sponsored program in Alberta, Canada (See question #24).

21. What are the benefits of the North Dakota Cloud Modification Project?

Several independent evaluations of the North Dakota Cloud Modification Project have been conducted to determine the effects of the project on rainfall, crop-hail damage, wheat yields, and economic effects. A 1997 study of crop-hail insurance data showed a 45 percent reduction of crop-hail damage in the seeded counties. Three independent studies on rainfall effects, most recently Johnson, 1985, found that rainfall was increased in the target counties and slightly downwind from 7 and 15 percent, an increase of up to an inch of additional growing season moisture. A study of wheat yields by Smith, et al., 1992, found an increase of 5.9 percent in the seeded counties versus an adjacent control area. Economic studies based on these results yield a benefit-to-cost ratio conservatively estimated at 50:1 for additional crop production. This ratio does not factor in the savings on property damage which is presumed to be substantial.

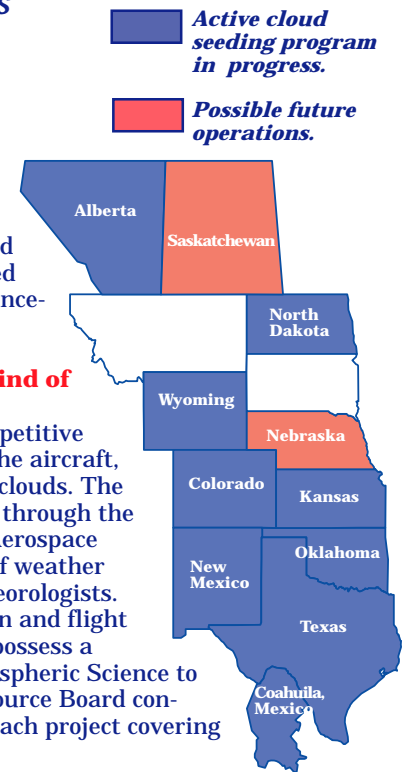
Wheat Yields in Control Area and NDCMP Target Areas?



Administration and Economics

22. Who else is doing weather modification?

The latest data from the World Meteorological Organization compiled for 1995 listed 84 projects ongoing worldwide in 26 countries. In 1996 the National Oceanic and Atmospheric Administration (NOAA) documented 45 projects conducted in 9 U.S. states. Project objectives included fog dispersal, snowpack and rainfall enhancement, and hail suppression.



23. Who seeds the clouds, and what kind of training is required?

The Atmospheric Resource Board via competitive bidding retains contractors who provide the aircraft, seeding equipment and pilots to seed the clouds. The ARB also maintains two intern programs through the University of North Dakota's Center for Aerospace Sciences for academic and field training of weather modification intern pilots and intern meteorologists. Pilots-in-command must meet certification and flight time requirements; Meteorologists must possess a Bachelor's degree in Meteorology or Atmospheric Science to qualify. In addition, the Atmospheric Resource Board conducts a three-day ground school prior to each project covering all pertinent aspects of the program.

24. If cloud seeding results in less hail, why aren't the insurance companies paying for it?

They aren't paying for the project in North Dakota, but in Alberta, Canada, the insurance industry wholly funds a hail suppression program for reduction of property damage. The five-year pilot program operates each year from June 1 through September 15 and will continue through the year 2000. If, after the first five years, it is demonstrated that the program has helped minimize property damage caused by hail, there is a good possibility the project will continue.

25. How can I get my county into the North Dakota Cloud Modification Project?

There are many ways to get your county into the North Dakota Cloud Modification Project. A petition collecting signatures numbering at least **20 percent** of the ballots cast in the most recent gubernatorial election presented to the county commission would place the issue on the next county-wide election ballot. A simple majority in the election would establish the authority to conduct cloud seeding. The second possibility would be to collect signatures numbering at least **51 percent** of the ballots cast in the most recent gubernatorial election. This petition, when presented to the county commission, would immediately establish the cloud seeding authority. The third option would be for the county water resource board to bring a resolution to the county commission for the creation of a weather modification authority. After a public hearing, a majority vote by the commission would

allow the county to participate in a trial program for up to four years, with ratification by county-wide election or 51 percent petition needed to continue the authority after the four-year trial period.

26. If it gets too wet, who tells the cloud seeders to stop?

Each county participating in the cloud seeding program has two local delegates on the District Operations Advisory Committee, which advises the operations crew on operations strategies. For instance, if a county or part of a county is extremely wet, cloud seeding could be suspended until drier conditions return.

27. How expensive is it to seed clouds?

There are significant costs associated with a cloud seeding project, but as all studies of the North Dakota project conclude, the benefits of the project far outweigh the costs (See question #21). For the 1998 North Dakota project, the average cost was about 8 cents per acre. This figure is based on total costs for all counties in the program divided by the total acreage of each county.

28. Who pays for cloud seeding in North Dakota?

Cloud seeding is paid for by the participating counties along with some state cost-sharing. In recent years, about 80 percent of the project has been funded through county taxes, with the remaining 20 percent picked up by the state.

REFERENCES

Changnon S.A., Jr., and F.A. Huff, 1972: Evaluation of Potential Effects of Weather Modification on Agriculture in Illinois. *Journal of Applied Meteorology*, 11, 376-384.

Johnson, H.L., 1985: **An Evaluation of the North Dakota Cloud Modification Project**. A final report to the North Dakota Weather Modification Board, June, 1985. 35 p.

Sell, R.S., and F.L. Leistriz, 1998: **Economic Impact of Reducing Hail and Enhancing Rainfall in North Dakota**. 29 p.

Smith, P.L., Jr., L.R. Johnson, D.L. Priegnitz, and P.W. Mielke, Jr., 1992: A Target-Control Analysis of Wheat Yield Data for the North Dakota Cloud Modification Project Region. *Journal of Weather Modification*, 24, 98-105.

Smith, P.L., Jr., L.R. Johnson, D.L. Priegnitz, B.A. Boe, and P.W. Mielke, 1997: An Exploratory Analysis of Crop Hail Insurance Data for Evidence of Cloud Seeding Effects in North Dakota. *Journal of Applied Meteorology*, 36, 463-473.



900 EAST BOULEVARD AVE, DEPT 410
BISMARCK, ND 58505 701)328-2788
<http://www.swc.state.nd.us/ARB/>